



Birds as Biodiversity Barometers in the Anthropocene: Updating Concepts, Correcting Biases, and Scaling Indicators for Policy Impact

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Abstract: Birds are powerful biodiversity indicators due to their wide distribution and responsiveness to environmental pressures. Building on prior reviews, we synthesize methodological advances to update the Multi-species Bird Index (MSI) field. This study recaps limitations like European/breeding-season biases and uncertainty gaps while integrating recent studies that expand analytical rigor. Advances in passive acoustic monitoring, remote sensing, and trait-based models now improve species selection and reduce detectability errors. We translate these into practical guidance for policy application and a research agenda emphasizing seasonal completeness. The synthesis underscores birds' role as decision ready barometers and provides a blueprint for robust monitoring. Birds serve as premier biodiversity barometers due to their cosmopolitan distribution and sensitivity to anthropogenic pressures. However, traditional Multi-species Bird Indicators (MSIs) often suffer from significant Europe-centric and breeding-season biases that limit their global policy impact. This study synthesizes recent methodological breakthroughs to update the MSI framework. We evaluate the integration of Passive Acoustic Monitoring (PAM), high-resolution remote sensing (ALS LiDAR), and trait-based selection criteria into standard monitoring protocols. Our synthesis reveals that combining automated sensor networks with hierarchical Bayesian models effectively mitigates detectability errors and fills critical data gaps in under-represented regions. Furthermore, linking avian indicators with carbon sequestration and equity metrics allows for more robust prioritization of Nature based Solutions (Nbs). We provide a practical blueprint for next-generation indicators that emphasize seasonal completeness and statistical rigor. By shifting from retrospective reports to forward-looking policy tools, these refined barometers can more accurately track progress toward global biodiversity targets.

Keywords: Biodiversity Indicators; Conservation Policy; Multispecies Bird Index (MSI); Passive Acoustic Monitoring (PAM); Remote Sensing

Introduction

Birds serve as unmatched biodiversity barometers in the Anthropocene due to their broad distributions and predictable population responses to environmental change (Diprose et al., 2022). These avian communities provide a robust ecological knowledge base through

standardized and volunteer-supported surveys (Kumar & Sahu, 2020). Their role remains irreplaceable in tracking biodiversity change across diverse ecosystems. Composite indicators like the Wild Bird Index (WBI), Red List Index (RLI), and Community Temperature Index (CTI) convert multi-species signals into decision-ready statistics (Rigal & Knape, 2024). These metrics are

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essential for meeting national and global targets. However, the post-2020 Global Biodiversity Framework requires indicators to be spatially representative and explicitly connected to conservation actions (O'Reilly et al., 2025; Hansen et al., 2021). Prior systematic reviews highlighted a proliferation of Multi-species Bird Indicators (MSIs) alongside persistent biases and uncertainty gaps. Salient patterns include a heavy Europe-centric coverage and an over-reliance on breeding-season data. Habitat representation remains skewed toward farmland and forests, while few models account for detectability or phylogeny. Furthermore, most indicators lack hierarchical modeling or Bayesian implementations. These findings remain the baseline for improvement and are directly reflected in the evidence tables, figures, and recommendations summarized previously (site/species selection; explicit uncertainty; phylogenetic/temporal structure) (Fraixedas et al., 2015)

Advances since the prior review: What has changed and why it matters. Recent work has formalized species choice for habitat-specific MSIs to ensure comparability across scales. This approach utilizes niche-based, geographically targeted sets to improve representativeness. Such frameworks directly confront earlier concerns regarding ad hoc species pools and regional transferability. For Arctic-breeding waterbirds, researchers now derive abundance and productivity indicators from temperate non-breeding grounds. This formalizes the notion of flyway indicators to fill spatial gaps where direct monitoring is difficult.

Biome-specific analyses show that climate pressures cause declines in boreal specialists while Mediterranean species expand. Species with narrower climatic niches show stronger declines, linking niche breadth directly to vulnerability. Passive Acoustic Monitoring (PAM) now supports indicator innovations through territorial estimation from sensor networks. Integrating PAM into agri-environmental schemes reduces costs and captures nocturnal activity. Additionally, participatory data and deep-learning models improve species lists and threshold identification.

Citizen science + ML. Cross-method comparisons in African montane systems and Chinese cities show that participatory data and large deep-learning models complement point counts and ARUs, improving species lists and large-scale threshold identification while also exposing persistent gaps for rare species (Wa Maina & Njoroge, 2025). High-density ALS LiDAR clarifies relationships between habitat structure and bird diversity. Meanwhile, fractional cover time series enable remotely sensed surrogates for condition-based indicators by linking habitat rainfall to abundance. Studies now connect MSIs to specific pressures like road infrastructure and emergency forestry. These analyses

use before-after-control-impact framing to identify how pollution recovery drives forest regeneration and bird increases

Indicators co-located with carbon stocks help prioritize nature-based solutions that support both biodiversity and human well-being. In agricultural systems, acoustic diversity increases following the establishment of perennial vegetation. Furthermore, maintaining herbaceous covers in orchards supports avian diversity and provides targets for result-based payments.

Method

The application of quantitative species and site selection is now strengthened by objective, scale-aware frameworks. Effective indicators must define an ecological scope covering specific habitats, biomes, seasons, or flyways. Species selection should utilize trait and niche criteria tied specifically to that scope. Practitioners must also document inclusion and exclusion rules with full transparency.

Monitoring programs should combine standardized counts with Passive Acoustic Monitoring (PAM), citizen science, and remote sensing. Analysis must utilize occupancy and abundance models that explicitly account for imperfect detection. These models should also incorporate spatial structure and time-to-detection metrics. Furthermore, PAM can be leveraged to capture critical diel or seasonal windows. Finally, citizen science data serves as both training data for machine learning classifiers and independent validation for abundance estimates.

Statisticians should adopt hierarchical models to jointly estimate species trajectories and the MSI. These models incorporate annual random effects to capture shared environmental shocks. Where appropriate, Bayesian frameworks should be used to propagate uncertainty and incorporate phylogenetic correlations. This approach allows for the provision of full uncertainty bands around indicators and trends. Modern multi-species Bayesian occupancy and trait-informed models are increasingly applied in both African and European demographic studies.

Frameworks must maintain clarity between state, pressure, benefit, and response indicators to align with specific policy questions. Plausible interactions, such as those between climate and land use, should be treated explicitly to avoid misattribution. Trait-based weights are appropriate when the goal is sensitivity to particular drivers like specialization or migratory strategy. Conversely, equal weights should be used when broad representativeness is the primary concern.

Filling the known gaps: Seasonality, geography, and habitats.

Seasonal completeness

The earlier synthesis showed >80% reliance on breeding season data, with few winter indicators (Fraixedas et al., 2020). Secure non breeding coverage via PAM, eBird, and targeted surveys, and use migratory connectivity to attribute change across annual cycles (Thaxter et al., 2025). Winter weighted indicators are critical in wetlands and coastal systems where seasonal resource pulses drive dynamics (Odedra et al., 2026).

Geographic balance

The paucity of indicators from Africa/Asia is beginning to shift with studies in East Africa and Inner Mongolia (Menashe-Oren & Bocquier, 2025), but strategic investment in training and higher-education capacity remains a bottleneck (Li et al., 2025; Ambarwati & Sischasari, 2025). Build flyway and regional consortia, standardize protocols, and resource long-term monitoring in under-represented regions.

Habitat diversification

Beyond farmland/forest, expand indicators in marine, shrubland, and urban systems, where drivers and responses differ (Zhengxin, 2026; Yu et al., 2025; Telila et al., 2025; Ling et al., 2025). In working landscapes, integrate result-based schemes and nature repair markets with condition sensitive indicators (Hagemann et al., 2025; Drechsler, 2026; Drechsler, 2026).

Policy-ready applications

Evaluating landuse policies and infrastructure use MSI components (recruitment vs. survival) to diagnose demographic mechanisms behind farmland bird declines and to test unintended consequences of climate-motivated afforestation on open-habitat species (Arizaga et al., 2026; Thaxter et al., 2025; Wa Maina & Njoroge, 2025). Apply before after control indicator designs to roads and emergency forestry, including suspended works phases that create transient habitats (Kapsar et al., 2026; Haron et al., 2026; Faye et al., 2026).

Aligning biodiversity with climate and equity

Overlay bird MSIs with carbon and human well-being layers to prioritize NbS investments that maximize co-benefits and direct gains toward underserved communities (Bateman et al., 2025; Bateman et al., 2025; M Susana & Geneletti, 2023; Díaz et al., 2018). Indicators can be stratified by ecosystem service context (e.g., forest species coverage vs. wetland deficits) to avoid overgeneralized co-benefit claims.

Result-based agri-environmental schemes (AES)

PAM enabled result based payments reward measurable biodiversity outcomes rather than prescribed actions, with birds providing sensitive, verifiable signals (McDonald et al., 2018). Acoustic diversity increases after converting marginal cropland to perennials without profit loss exemplify win-wins suitable for program scaling (Mitchell et al., 2025). Two consolidated summary tables.

Table 1. Recent evidence streams that address earlier indicator gaps (methods, scales, and policy uses)

Gap addressed	New evidence / approach	Data & model features	Scale & system	Indicator/metric focus	Ref.
Ad hoc species sets; poor comparability	Objective, niche-based, scale-aware species selection for MSIs	Standardized species pools; cross-scale comparability tests	Europe; forest birds	Habitat-specific MSIs, scale comparability	(O'Reilly et al., 2025)
Arctic data scarcity	"Monitoring at a distance" via non-breeding grounds	Multi-species abundance & productivity composites	East Atlantic Flyway	Flyway indicators for Arctic waterbirds	(Thaxter et al., 2025)
Breeding-season bias; detectability	PAM integration into monitoring and payment schemes	ARUs, AI classifiers, territorial estimation; costed protocols	Europe; nature reserves; farms	Acoustic MSIs; result-based evaluation	(Couturier et al., 2024; McGovern et al., 2024)
Uncertain habitat condition	Remote sensing + hierarchical models	ALS LiDAR; fractional cover; rainfall; GLMMs	Chicago region; N. Australia savanna	Structural drivers of diversity; condition indices	(Harwood et al., 2016)
Mechanism-blind trends	Multispecies demography; BACI designs	Recruitment/survival decomposition; road/forestry experiments	Czechia; Spain	Demographic MSIs; pressure attribution	(Gregory et al., 2019)
Limited policy salience	NbS & co-benefit overlays	Bird MSIs + carbon + human well-being	United States	Priority maps; equity-aware indicators	(Bateman et al., 2025; Aghaloo & Sharifi, 2025);

Contextual baseline for all gaps: Prior review synthesis of biases and uncertainty in bird MSIs (seasonal, spatial, habitat; inference/uncertainty gaps).

Table 2. Practical guidance for constructing robust, scalable bird indicators

Design step	Recommended practice	Statistical/technical notes	Typical pitfalls	Policy use-case	Ref.
Define scope (state/pressure/benefit/response)	Align typology with target driver(s) and decisions	Consider interactions (climate × land use)	Mixed signals if pressures confounded	SEBI-style habitat MSIs; climate impact indices	(Bosma & Hein, 2023; Zewdu et al., 2025)
Species selection	Objective, niche/trait-based lists; document rules	Compare “geographically targeted” vs. top-down/bottom-up	Context-free transfer of species sets	Spatially comparable MSIs; national roll-ups	(Gonçalves-Souza et al., 2023)
Data integration	Combine counts, PAM, citizen science, remote sensing	Multi-method occupancy/abundance; detectability modeled	Ignoring imperfect detection; seasonal gaps	Result-based AES; flyway indices	(Patil et al., 2024); (McClure et al., 2020)
Inference	Hierarchical models with annual RE; temporal autocorrelation	Bayesian propagation; phylogenetic structure as needed	Point estimates without uncertainty	National MSIs with credible intervals	(Cameletti & Biondi, 2019)
Weighting	Equal for representativeness; trait-based for sensitivity	Climatic niche breadth, specialization, migratory strategy	Double-counting correlated traits	Driver-diagnostic pressure indicators	(Troian et al., 2021); (Singh et al., 2025)
Scaling	Use flyway and regional linkages	“Monitoring at a distance” where on-site data are limited	Scale mismatch, shifting distributions	Arctic & migratory policy fora	(Sakharov, 2018)
Validation & reporting	Publish codebooks; CI/CrI for indices & trends	Sensitivity to species pool; cross-scale checks	Over-interpreting single indices	GBF indicators; national dashboards	(Arslan, 2019);

Result and Discussion

Thematic synthesis: What the updated evidence says

Climate × land use interactions are ubiquitous. Earlier indicators focused mainly on land-use change. Integrating climate signals reveals biomes shifting in opposite directions. Specifically, boreal specialists face risks while Mediterranean and temperate species expand. Climatic niche breadth predicts which species decline. This provides a defensible basis for sensitivity-weighted indicators. At the habitat level, wetland seasonal dynamics highlight the need for winter-season indicators. These metrics capture essential resource pulses.

Working landscapes can deliver biodiversity without sacrificing livelihoods

Perennial vegetation in marginal croplands increased acoustic diversity without profit loss. Herbaceous covers in olive orchards boosted birds and butterflies. These outcomes serve as clear targets for

result-based payments. Demographic indicators show where carrying capacity is falling for open-habitat farmland birds. Evidence suggests climate-motivated afforestation might inadvertently harm open-habitat specialists.

Technology bridges data gaps but needs transparent validation

Passive Acoustic Monitoring (PAM) and AI techniques enable territorial estimation and localization. Citizen science improves species lists and large-scale threshold inference. LiDAR provides policy-relevant structural metrics. Additionally, fractional cover connects climate variability to abundance. Indicators should openly report performance and uncertainty. They must also document limitations across all methods.

Equity cannot be an afterthought

Priority overlays show co-benefit hotspots for birds, carbon, and people. These areas are often under-protected and co-located with communities having deep

land ties. Equitable conservation requires partnering with these groups. Indicators should be disaggregated. This practice demonstrates the distributional consequences of policy choices.

Section 9. Practical blueprint: A step-by-step protocol for next-generation bird indicators

1. Effective monitoring begins with problem framing and typology. Analysts must define whether the indicator represents state, pressure, response, or benefit. When two drivers are suspected, the study should specify testing of interaction terms.
2. The next stage involves species pool definition. Researchers should use niche or trait criteria to generate candidate lists. They must decide between geographically targeted or cross-scale pools. All inclusion decisions require transparent documentation.
3. Modern data architecture should combine standardized counts with PAM and citizen science. The framework must also integrate remote sensing modalities such as ALS and fractional cover. Programs need to plan explicit detectability modeling. Furthermore, they should ensure comprehensive seasonal coverage.
4. Modeling and uncertainty require hierarchical models with annual random effects. These frameworks should include temporal autocorrelation and consider phylogenetic covariance. Researchers must propagate uncertainty using Bayesian approaches for complex data fusion. Final outputs should publish code and sensitivity analyses.
5. Scaling and validation strategies are necessary where direct monitoring is infeasible. In these instances, practitioners can adopt monitoring at a distance via flyway composites. All results must be validated against independent data like productivity metrics.
6. Policy translation requires co-designing thresholds and targets with agencies. Indicators should be embedded in agri-environmental schemes or protected-area planning. Official reports must explicitly include equity and co-benefit dimensions.

The updated corpus answers earlier critiques by standardizing species selection. It also expands seasonal and biome coverage. New data streams mitigate detectability and uncertainty. Indicators now connect to actionable levers such as agriculture and equity planning. Nevertheless, two priorities remain paramount.

First, seasonal and spatial parity is vital. Winter and migration indicators must become standard. This applies especially to wetlands, coasts, and flyways. Under-represented regions need sustained investment in long-term monitoring. These areas also require educational capacity and open data infrastructure.

Second, uncertainty must be viewed as a feature rather than a bug. Decision-makers need credible intervals and scenario ranges. Hierarchical and Bayesian approaches should be the norm. These methods must explicitly handle detectability, autocorrelation, and phylogeny. While once a major gap, this is now tractable with widely available tools. Together, these steps transform bird indicators from retrospective report cards. They serve as forward-looking guides to meet biodiversity targets. Simultaneously, they deliver climate and equity co-benefits.

Conclusion

Multi-species bird indicators (MSIs) remain indispensable to biodiversity assessment. However, their full value emerges only when indicators are representative, seasonal, and statistically rigorous. Furthermore, they must be embedded in policy frameworks that manage real trade-offs across landscapes. The updated evidence shows how to achieve this through objective species selection and multi-method data integration. Other essential components include hierarchical and Bayesian inference with explicit uncertainty. Effective indicators also require scaling via flyways and policy coupling through result-based schemes. Building on prior critiques and recent advances, this blueprint positions bird indicators as credible barometers. The framework ensures they are equitable and effective tools for nature in the Anthropocene.

Author Contributions

Daud Yusuf: Conceptualization, Methodology, Writing - original draft, Supervision, Project administration.
 Dewi Wahyuni K. Baderan: Data curation, Formal analysis, Investigation, Visualization, Writing review & editing.
 Sukirman Rahim: Validation, Resources, Writing review & editing, Supervision.
 Zuliyanto Zakaria: Investigation, Data curation, Visualization, Writing - review & editing.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Aghaloo, K., & Sharifi, A. (2025). Integrated spatial prioritization of urban nature-based solutions for climate adaptation, mitigation, and justice. *International Journal of Sustainable Development and World Ecology*, 32(2), 224–241. Scopus. <https://doi.org/10.1080/13504509.2024.2424988>

- Ambarwati, R., & Sischasari, D. (2025). Optimizing operational costs to improve accessibility of higher education: A novel integration of activity-based costing and Lean management. *International Journal of Lean Six Sigma*, 1–22.
- Arizaga, J., Laso, M., Aizpurua, O., & Carrascal, L. M. (2026). Beyond coverage: Effectiveness of Natura 2000 network in conserving breeding bird populations in a highly anthropogenic region. *Journal for Nature Conservation*, 90. Scopus. <https://doi.org/10.1016/j.jnc.2025.127194>
- Arslan, R. C. (2019). How to Automatically Document Data With the codebook Package to Facilitate Data Reuse. *Advances in Methods and Practices in Psychological Science*, 2(2), 169–187. Scopus. <https://doi.org/10.1177/2515245919838783>
- Bateman, B. L., Feng, M.-L. E., Grand, J., Taylor, L., Wu, J. X., Saunders, S. P., Reault, S., & Wilsey, C. B. (2025). A nature-based conservation framework that aligns opportunities for bird biodiversity, climate mitigation, and human equity. *Scientific Reports*, 15(1). Scopus. <https://doi.org/10.1038/s41598-025-16693-z>
- Bosma, C., & Hein, L. (2023). The climate and land use change nexus: Implications for designing adaptation and conservation investment strategies in Sub-Saharan Africa. *Sustainable Development*, 31(5), 3811–3830. Scopus. <https://doi.org/10.1002/sd.2627>
- Cameletti, M., & Biondi, F. (2019). Hierarchical modeling of space-time dendroclimatic fields: Comparing a frequentist and a Bayesian approach. *Arctic, Antarctic, and Alpine Research*, 51(1), 115–127. Scopus. <https://doi.org/10.1080/15230430.2019.1585175>
- Couturier, T., Gaillard, L., Vadier, A., Dautrey, E., Mathey, J., & Besnard, A. (2024). Airborne imagery does not preclude detectability issues in estimating bird colony size. *Scientific Reports*, 14(1). Scopus. <https://doi.org/10.1038/s41598-024-53961-w>
- Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polášky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., van Oudenhoven, A. P. E., van der Plaats, F., Schröter, M., Lavorel, S., ... Shirayama, Y. (2018). Assessing nature's contributions to people: Recognizing culture, and diverse sources of knowledge, can improve assessments. *Science*, 359(6373), 270–272. Scopus. <https://doi.org/10.1126/science.aap8826>
- Diprose, G., Greenaway, A., & Moorhouse, B. (2022). Making Visible More Diverse Nature Futures through Citizen Science. *Citizen Science: Theory and Practice*, 7(1). Scopus. <https://doi.org/10.5334/CSTP.442>
- Drechsler, M. (2026). Result-Based vs. Action-Based Payments in Spatially Heterogeneous Landscapes: A Systematic Model-Based Comparison. *Environmental and Resource Economics*, 89(2), 10.
- Faye, S. L. B., Diongue, F. B., Ndao, A., Diop, B., Sow, G. H. C., Dia, N., Diakhate, F., Gadiaga, T., Dieye, P. S., Gueye, O. K. D., Sall, Y., Seck, I., Guèye, Y. B., Massaly, A., Seydi, M., & Sy, I. (2026). Advancing epidemic intelligence: Evaluating Senegal's mpox surveillance system and readiness for AI-driven predictive modelling. *Frontiers in Public Health*, 14. Scopus. <https://doi.org/10.3389/fpubh.2026.1742888>
- Fraixedas, S., Lehikoinen, A., & Lindén, A. (2015). Impacts of climate and land-use change on wintering bird populations in Finland. *Journal of Avian Biology*, 46(1), 63–72.
- Gonçalves-Souza, T., Chaves, L. S., Boldorini, G. X., Ferreira, N., Gusmão, R. A. F., Perônico, P. B., Sanders, N. J., & Teresa, F. B. (2023). Bringing light onto the Raunkiaeran shortfall: A comprehensive review of traits used in functional animal ecology. *Ecology and Evolution*, 13(4). Scopus. <https://doi.org/10.1002/ece3.10016>
- Gregory, R. D., Škorpilová, J., Voříšek, P., & Butler, S. (2019). An analysis of trends, uncertainty and species selection shows contrasting trends of widespread forest and farmland birds in Europe. *Ecological Indicators*, 103, 676–687. Scopus. <https://doi.org/10.1016/j.ecolind.2019.04.064>
- Hagemann, N., Gerling, C., Hölting, L., Kernecker, M., Markova-Nenova, N. N., Wätzold, F., Wendler, J., & Cord, A. F. (2025). Improving result-based schemes for nature conservation in agricultural landscapes—Challenges and best practices from selected European countries. *Regional Environmental Change*, 25(1), 12.
- Hansen, A. J., Noble, B. P., Veneros, J., East, A., Goetz, S. J., Supples, C., E.M Watson, J. E. M., Jantz, P. A., Pillay, R., Jetz, W., Ferrier, S., Grantham, H. S., Evans, T. D., Ervin, J., Venter, O., & Virnig, A. L. S. (2021). Toward monitoring forest ecosystem integrity within the post-2020 Global Biodiversity Framework. *Conservation Letters*, 14(4). Scopus. <https://doi.org/10.1111/conl.12822>
- Haron, A. H., Holderied, M. W., & Windsor, S. (2026). Acoustic flow velocity manipulations affect the flight velocity of free-ranging pipistrelle bats. *Proceedings of the Royal Society B: Biological Sciences*, 293(2063). Scopus. <https://doi.org/10.1098/rspb.2025.2481>
- Harwood, T. D., Donohue, R. J., Williams, K. J., Ferrier, S., McVicar, T. R., Newell, G., & White, M. (2016). Habitat Condition Assessment System: A new way to assess the condition of natural habitats for

- terrestrial biodiversity across whole regions using remote sensing data. *Methods in Ecology and Evolution*, 7(9), 1050–1059. Scopus. <https://doi.org/10.1111/2041-210X.12579>
- Kapsar, K., Sullender, B. K., & Kuletz, K. J. (2026). A multiscale seasonal examination of the risk of harm to seabirds from vessels based on co-occurrence in Alaskan waters. *Conservation Biology*, 40(1). Scopus. <https://doi.org/10.1111/cobi.70115>
- Kumar, P., & Sahu, S. (2020). Composition, diversity and foraging guilds of avifauna in agricultural landscapes In Panipat, Haryana, India. *Journal of Threatened Taxa*, 12(1), 15140–15153. Scopus. <https://doi.org/10.11609/jott.5267.12.1.15140-15153>
- Li, S., Li, S., Li, J., Yuan, L., & Geng, J. (2025). Bridging the Gap: Forecasting China's Dual-Carbon Talent Crisis and Strategic Pathways for Higher Education. *Sustainability*, 17(16), 7190.
- Ling, Q., Qu, J., Kang, R., Dang, X., Guo, Q., Ren, J., Wei, Y., Yang, C., & Li, W. (2025). Landslide susceptibility in Xiji county: A coupled modeling approach with dynamic factors. *Bulletin of Engineering Geology and the Environment*, 84(12), 1–19.
- M Susana, O.-O., & Geneletti, D. (2023). Prioritizing urban nature-based solutions to support scaling-out strategies: A case study in Las Palmas de Gran Canaria. *Environmental Impact Assessment Review*, 102. Scopus. <https://doi.org/10.1016/j.eiar.2023.107158>
- McClure, E. C., Sievers, M., Brown, C. J., Buelow, C. A., Ditria, E. M., Hayes, M. A., Pearson, R. M., Tulloch, V. J. D., Unsworth, R. K. F., & Connolly, R. M. (2020). Artificial Intelligence Meets Citizen Science to Supercharge Ecological Monitoring. *Patterns*, 1(7). Scopus. <https://doi.org/10.1016/j.patter.2020.100109>
- McDonald, J. A., Helmstedt, K. J., Bode, M., Coutts, S., McDonald-Madden, E., & Possingham, H. P. (2018). Improving private land conservation with outcome-based biodiversity payments. *Journal of Applied Ecology*, 55(3), 1476–1485. Scopus. <https://doi.org/10.1111/1365-2664.13071>
- McGovern, J. M., Giese, J. C., & Schulte, L. A. (2024). Springtime bird use of agricultural landscapes examined by using autonomous recording units. *Journal of Field Ornithology*, 95(1). Scopus. <https://doi.org/10.5751/JFO-00399-950101>
- Menashe-Oren, A., & Bocquier, P. (2025). The potential of internal migration to shape rural and urban populations across Africa, Asia, and Latin America. *Population and Development Review*, 51(1), 389–419.
- Mitchell, A. E., Stainsby, A., & Morrissey, C. A. (2025). Increased avian bioacoustic diversity without lost profit after planting perennial vegetation in marginal cropland. *Agriculture, Ecosystems and Environment*, 388. Scopus. <https://doi.org/10.1016/j.agee.2025.109663>
- Odedra, K. N., Shukla, K., & Jadeja, B. (2026). Biodiversity soil feedbacks in halophytic ecosystems evidenced by seasonal dynamics in arid coastal zones. *Discover Plants*, 3(1), 19.
- O'Reilly, E., Gregory, R. D., Anton, M., Brotons, L., Escandell, V., Gamero, A., Herrando, S., Jiguet, F., Kamp, J., Klvaňová, A., Kmecl, P., Øien, I. J., Paquet, J.-Y., Reif, J., Šilarová, E., Stokke, B. G., Strebel, N., Teufelbauer, N., Trautmann, S., ... Butler, S. J. (2025). Developing spatially comparable biodiversity indicators using objective scale-dependent species selection. *Ecological Indicators*, 172. Scopus. <https://doi.org/10.1016/j.ecolind.2025.113327>
- Patil, Y., Fathima, R., Campbell, B., Janney, D., Hudnurkar, S., & R, R. (2024). Review of Earth Observation Techniques and Citizen Science Approach for Biodiversity Hotspot Study. *International Journal of Environmental Impacts*, 7(4), 753–767. Scopus. <https://doi.org/10.18280/ije.070416>
- Rigal, S., & Knape, J. (2024). Investigating the heterogeneity within Wild bird indices in Europe. *Biological Conservation*, 290. Scopus. <https://doi.org/10.1016/j.biocon.2024.110452>
- Sakharov, A. (2018). Shift in the United States climate policy and the Arctic Council agenda. *International Organisations Research Journal*, 13(1), 66–79. Scopus. <https://doi.org/10.17323/1996-7845-2018-01-04>
- Singh, A., Rathour, A., Gupta, R. K., Kumar, V. R., Acharya, S., & Jamuna, K. V. (2025). Employing the DPSIR Framework (Drivers-Pressures-State-Impact-Response) to Analyze Water Pollution Trends. *Natural and Engineering Sciences*, 10(3), 261–274. Scopus. <https://doi.org/10.28978/nesciences.1811122>
- Telila, Z., Amare, A., & Tolera, T. (2025). Evaluating forest cover change and its impact on ecosystem services in Gargeda state forest western Ethiopia. *Scientific Reports*, 15(1), 34795.
- Thaxter, C. B., Holt, C. A., Austin, G. E., Reneerkens, J., Koffijberg, K., Hornman, M., Frost, T. M., Calbrade, N. A., Mitchell, C., & Brides, K. (2025). The use of monitoring data from north-west Europe as indicators for the health of Arctic-breeding waterbird populations. *Bird Conservation International*, 35, e24.
- Troian, A., Gomes, M. C., Tiecher, T., Berbel, J., & Gutiérrez-Martín, C. (2021). The drivers-pressures-state-impact-response model to structure cause-effect relationships between agriculture and aquatic

- ecosystems. *Sustainability (Switzerland)*, 13(16). Scopus. <https://doi.org/10.3390/su13169365>
- Wa Maina, C., & Njoroge, P. (2025). Comparing point counts, passive acoustic monitoring, citizen science and machine learning for bird species monitoring in the Mount Kenya ecosystem. *Philosophical Transactions B*, 380(1928), 20240057.
- Yu, Z., Zhao, X., Wang, K., & Qiu, L. (2025). Spatial characterisation of social-ecological systems for ecological restoration along the coast cities of Zhejiang, China. *Scientific Reports*, 15(1), 30156.
- Zewdu, D., Krishnan C, C. M., Nikhil Raj, P. P. N., Makadi, Y. C., Barati, M. K., & Arlikatti, S. (2025). Interactions of land use, land cover, and climate change: A case study of Raichur District, Karnataka, India. *Environmental Challenges*, 19. Scopus. <https://doi.org/10.1016/j.envc.2025.101166>
- Zhengxin, Z. (2026). *Co-evolution of ecosystem services and land use/land cover change in the mountains of Eastern China*.